

The Composition of Meat Flavor

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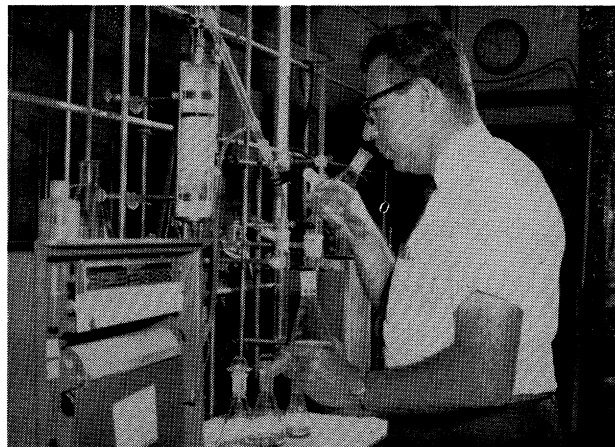
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THE TRADE is aware that the popularity of beef is declining because of its lack of pleasing flavor, a deficiency of quality that is the result of modern speed-up methods of beef production." This misleading statement, appearing in a popular consumer publication (1), illustrates the lack of knowledge about beef flavor and factors involved in its development.

Ever since man began eating meat, however, he has been interested in its flavor. The various preparation, curing and spicing methods that have been developed over the years did very little to improve the nutritional or energy values of the meat. The culinary tricks were primarily to enhance or alter the flavor of the meat, to make it more palatable or to supply a new flavor "sensation."

What is flavor? Ignoring extraneous factors such as texture, toughness, appearance, etc., flavor is the combined effect of taste and aroma. Taste covers the oral sensations of sweet, sour, salt and bitter; hot and cold; and the indefinable "mouth feel."

Aroma, or odor, is due to the stimulation of the olfactory receptors. Aroma is not restricted to what we smell. An important part of the so-called "taste" of a material is due to the aroma that stimulates the olfactory receptors through the passageways connecting the mouth and the nasal cavity.

This can be readily demonstrated by pinching the nose closed for a few seconds while chewing a flavorful piece of meat. Thus, while taste does contribute significantly, aroma is usually meant when we refer to the flavor of meat, and most of the research on meat flavor has concerned itself with aroma, the volatile compounds that are released in the preparation of the meat.

Meat is composed of an extremely complex collection of chemicals, each class containing many individual compounds (Table 1 shows some of these classes). The sugars, for instance, include 4-, 5-, 6-, or 7-carbon compounds that may exist free or combined with phosphorus. They may be simple or joined together in a complex molecule.

The sugars may occur complexed with fats as glycolipids, or with proteins as glycoprotein. Lipids vary from neutral fats to complex sterols, and proteins include structural elements, enzymes, pigments, etc. In addition, there are non-protein nitrogenous compounds, acids, salts and many other components. It is from this mass of compounds that flavor is developed.

GENETIC CHANGES: While in general the flavor of meats is constant and recognizable, there are differences from animal to animal, and even within the same animal not every piece of meat has the same flavor. The role of genetics can be recognized because there are differences

in the flavor of meat between one species of animal and another, but less recognizable is the difference between animals of the same species. As each animal is an individual, unique genetic changes may affect its metabolism which, in turn, can influence the chemical composition of its tissues and thus the flavor.

The function of a muscle or organ may involve differences in its chemical composition and flavor, and its location in the body also may influence the flavor. The general health of the animal and the nature of the diet may affect the flavor of the meat. Johnson and Vickery (2) found the pH of the muscle from starving animals is lower than in muscle from normal, well-fed animals. While the relationship of the pH of the meat to flavor has not been completely investigated, there may be a significant correlation.

Important chemical changes occur in animal tissue just before and immediately after slaughter. The change in pH, the breakdown of adenosine triphosphate (ATP) and other enzymatic activities occur in a non-reversible direction after death. The study of these changes is going on now and their influence on meat flavor has yet to be evaluated.

The most widely recognized condition for development of desirable meat flavor is the "ripening" or aging period after slaughter. Under proper conditions, enzyme activity induces changes in the meat that give good flavors when it is prepared. "Over-ripening," on the other hand, produces undesirable breakdown products that develop into unpleasant flavor notes.

Raw meat has relatively little flavor; it is primarily salty to the taste with a characteristic bloody or serummy aroma. Only on cooking is the true flavor developed. Chemical reactions occur that are brought about by the addition of heat, and we are attracted by the odor of the end products of these reactions. The nature of the end products is affected by the amount of heat used. Boiling meat in water at 100° C. results in an overall flavor which differs completely from that of a steak exposed to dry heat at 150°C.

TWO WAYS: The problem of meat flavor, or aroma,

TABLE 1. CLASSES OF CHEMICALS FOUND IN MEAT

Lipids	Proteins
Neutral	Structural
Phospholipids	Functional
Sterols	Nucleic Acids
Carbohydrates	Ribonucleic Acid
Free	Deoxyribonucleic Acid
Complex	Nucleotides
Phosphorylated	Nucleosides
Non Protein Nitrogen	Free Bases
Amino Acids	Acids
Anserine, carnosine	Free Fatty Acids
and other peptides	Inorganic Acids
Creatine, Creatinine	Metabolic Acids
Inorganic Elements	Vitamins

can be studied in two ways: 1) by determining the precursors, the chemical compounds present in meat that are responsible for aroma when heated, and 2) by identifying the odorous compounds after they are formed by heat.

The study of flavor precursors is complicated by the fact that practically all the components of meat will give rise to odorous products when heated. Sugars form brown, polymerization products with a sweet, caramel odor. Fats break down to a variety of odorous acids, ketones and aldehydes, and the proteins release amines and other acrid products.

To complicate this further, there also are interactions and secondary reactions, such as the Strecker degradation in which amino acids react with sugars or other dicarbonyl compounds to form a variety of odorous aldehydes, depending on the amino acid. Rothe and Voigt (3) heated the 5-carbon sugar, xylose, with some amino acids and obtained aromas that could be associated with a number of food products.

TABLE 2. AROMAS DEVELOPED ON HEATING AMINO ACIDS WITH XYLOSE (3)

Amino Acid	Aroma
Serine	Caramel
α -Alanine	Malt
α -Aminobutyric acid	Walnut
Proline	Browned flour
Valine	Malt
Leucine	Malt
Cysteine	Burnt protein
Cystine	Puffed rice
Methionine	Cooked cabbage
Tryptophane	Browned fat
Phenylalanine	Honey

These amino acids and the corresponding odors are listed in Table 2. All these amino acids are present in meat, combined with protein or in the free state; so these aromas may contribute to the overall meat flavor. The type of sugar also is important because sugars react with amino acids at different rates.

To isolate the aroma precursor compounds, meat is separated, or fractionated, by a series of procedures that, hopefully, will not alter the desired components. The initial step in any fractionation system is an extraction to remove the flavor precursors from the bulk of the meat. Water has been shown to accomplish this in a satisfactory manner (4).

Ground beef, thoroughly mixed with cold water for several hours and then made into a hamburger and broiled, will have very little taste. It also will be tough and dry. The water extract, on the other hand, releases a series of odors when it is heated. At the boiling point, the extract has a brothy aroma; as the water boils off and the dry solids are pyrolyzed by exposure to temperatures in the order of 150° C., the odor is that of roast beef or broiling steak. Continued heating results in an acrid, burnt protein-like odor.

ESSENTIAL ELEMENTS: After carrying through a series of separations, Batzer, Santoro and Landmann (5, 6) found that the essential elements for producing the flavor of cooked beef on heating were inosinic acid and a glycoprotein or mixtures of glucose and the amino acids found when the glycoprotein was broken down by heating with acid. A number of other compounds also present in the fractions do not give a meaty aroma when heated with glucose or inosine, but the authors indicated their presence is necessary for a fully developed meat flavor.

Wasserman and Gray (7), following a fractionation procedure similar to that of Batzer, could not confirm their results. Using the characteristic broiled steak aroma produced on pyrolysis at 150° C. to follow their fractionation procedure, they found that inosine was removed from the precursor fraction without affecting

the aroma, and inosinic acid was present in trace amounts only. Furthermore, proteins and glycoproteins were not present in their fractions, only amino acids and the dipeptides anserine and carnosine.

Macy, Naumann and Bailey (8) carried the fractionation through the dialysis step only and then analyzed the low molecular weight material before and after heating at 100° C. for one hour. This was done with beef, pork and lamb. The compounds taurine, alanine, anserine and carnosine were present in greatest concentration, and in beef suffered the greatest losses as a result of cooking. Two sugars, ribose and glucose, also were present in the dialysates; after heating, the ribose disappeared completely while about 60 per cent of the glucose remained.

Macy, Naumann and Bailey concluded that ribose was the more labile, and from this implicated inosinic acid, which contains ribose, as being strongly involved in browning and flavor formation. However, it is interesting to note that there was from 40 to 200 times as much glucose as ribose present and considerably more glucose than ribose disappeared during the one hour of boiling.

A complete analysis of the components of beef extract was made by Bender, Wood and Palgrave (9). These authors also analyzed raw beef. They found some changes in the amount of some of the components as a result of the cooking process in making the extract. Wood (10) also studied model systems in which he heated various sugars and amino acids. He claimed that ribose-5-phosphate was the sugar that reacted with the amino acids to produce a meaty aroma.

PROCESSES: Patents have been issued for processes developing meaty aromas. C. G. May and co-workers proposed the reaction of sugars, preferably ribose, heated for long periods of time with cysteine and other amino acids or proteins and protein hydrolysates (11). In place of the sugar, May also suggested heating aldehydes (12) or furan compounds (13) with cysteine and other amino acids.

A number of the foregoing studies seem to involve ribose, inosine and inosinic acid in the development of flavor. While ribose is a 5-carbon sugar that is an intermediate in normal metabolism, very little is normally found in living tissue. It can accumulate after the death of the animal as a breakdown product of the inosinic acid and inosine. They are related as follows:

Adenosine triphosphate (ATP)→adenosine monophosphate (AMP)→Inosine monophosphate (IMP) or inosinic acid→inosine→hypoxanthine + ribose + phosphate.

The sugar, ribose, is part of the complex molecule ATP, which very quickly loses phosphorus as a result of enzyme action after death. An enzymatic modification converts AMP into inosinic acid. The disodium salt of inosinic acid is one of the new flavor enhancers. During the aging period, the inosinic acid is broken down to its individual components, hypoxanthine, ribose and phosphorus.

It is interesting to note that in the fish industry, where freshness is of utmost importance, the development of hypoxanthine is being proposed as a test for freshness, since hypoxanthine imparts an undesirable taste. Meat, on the other hand, is aged and the flavor considered most desirable at a stage when considerable hypoxanthine has accumulated.

ISOLATION OF CHEMICALS: The second approach to the study of meat flavor involves isolation and identification of the chemicals that are formed on heating and are responsible for the desirable odor. Much of the research on meat aroma has been carried out by trapping the volatile compounds from cooking meat.

For the most part, this has been accomplished by

boiling a slurry of meat and water for hours and sweeping the volatile compounds through a series of very cold traps or traps containing chemical solutions that will react specifically with certain classes of compounds present in the vapor. Under these conditions of preparation, the only aroma to be expected would be that of boiled meat; temperature and moisture conditions are such that other aromas would not be developed.

Determining the pathways by which the aroma components are formed is complicated by the use of whole meat with its many component factors, and this is complicated even further by the long hours at high temperatures in which many side and secondary reactions may occur.

Hornstein and co-workers (14, 15) used another technique in their study of volatile components. A freeze-dried water extract of beef containing the flavor precursors was exposed to 100° C. temperatures under conditions of high vacuum, and the volatiles formed were trapped at liquid nitrogen temperatures. The frozen material, still under vacuum, was allowed to come to room temperature, permitting the more volatile compounds to distill into new traps cooled with either liquid nitrogen or dry ice-isopropyl alcohol.

The low-boiling, volatile fraction was unpleasant smelling, while the high-boiling residue had a pleasant, fruity aroma that developed into a meaty aroma on standing. This fraction was identified as containing principally ammonium lactate. Since this chemical alone has no meaty aroma, the component or components responsible for the odor probably were present in trace quantities and thus not noticed.

The compounds identified in the low-boiling fractions were similar to those reported by investigators using other techniques.

Compounds in the volatile aroma from cooked beef, lamb and pork are listed in Table 3. They are composed principally of carbonyls, fatty acids and sulfide compounds. None of these components individually smells like meat, and "compounding," or mixing them together, also fails to yield a meaty aroma.

LOWER FATTY ACIDS: The origins of the compounds in Table 3 would be of interest as an indication of the mechanism of the reactions forming the flavor components, but no work has been reported on this aspect of flavor studies. The lower fatty acids may arise from the oxidation and degradation of fatty acids. The sulfur compounds can only originate from three amino acids (or the proteins containing them): cysteine, cystine and methionine.

Hamm and Hofmann (16) indicated that heating meat to about 70° C. resulted in an increase in —SH, or sulfhydryl, bonds as the protein denatured and unfolded. At 110° C., however, the —SH groups were oxidized to —S—S— (disulfide) bonds and became unavailable for reactions. This formation of —S—S— bonds also leads to increased toughness of the meat.

The origin of the sulfides themselves is not clear. Many may be formed as a result of interaction of sulfur released from cystine and cysteine with other compounds formed during heating. The odors of many of the sulfur compounds are very strong and they can be detected when present in extremely low concentration. While they are present in meat flavor, their importance is not known. But it has been shown that the sulfides, particularly H₂S, are major contributors to chicken flavor (17).

The third major class of compounds identified in meat volatiles are the carbonyls. These ketones and aldehydes may arise from the amino acids as a result of interaction with sugars through the Strecker degradation, or by

TABLE 3. VOLATILE COMPONENTS OF MEAT (14, 21, 22, 23, 24)

Carbonyls	Acids	Sulfur
Formaldehyde	Formic	H ₂ S
Acetaldehyde	Acetic	MeS
Propionaldehyde	Propionic	Me ₂ S
n-Hexanal	Butyric	Me ₂ S ₂
iso-Butyraldehyde	iso-Butyric	CH ₃ SH
iso-Valeraldehyde	Alcohols	CH ₃ CH ₂ SH
Acetone	Methanol	Carbon dioxide
Methyl isopropyl ketone	Ethanol	Ammonia
Methyl ethyl ketone		Methylamine
Diacetyl		

degradation of the fats.

The fats have been studied to some extent for their role in flavor formation. Hornstein (4, 14) studied the free fatty acids in beef, pork and lamb and the carbonyls formed on heating the fats. He found that heating the fat at 100° C. in a vacuum resulted in little or no change in the concentration of the fatty acids, and carbonyls were not formed. On the other hand, heating in air gave an increase in the fatty acid concentration due to hydrolysis of the glycerides. Carbonyl compounds also were formed, indicating oxidation of the fatty acids.

Identification of the various carbonyls revealed differences among the three types of meat. There were about four times as much unsaturated carbonyls in pork as in beef, and only traces in lamb fat volatiles. There also were differences in the concentration and distribution of the free fatty acids.

While the role of fatty acids in flavor has not been fully clarified as yet, Hornstein indicated that aromas from the lean meat of beef, pork and lamb were essentially the same and the species' specificity resided in the fat. One factor to consider in this respect is that the fat may act as a reservoir or depot for the aromas that have been developed from other muscle components.

CURED HAMS: Two studies have been reported on the compounds recovered from cured hams. Cross and Ziegler (18) used hams injected with pickle, cured for five days, canned and cooked at 75° C. to an internal temperature of 70° C. The volatile compounds from heated pieces of meat were trapped in various reagent solutions.

Table 4 shows the average quantity of aldehydes re-

TABLE 4. COMPONENTS OF CURED HAMS

Components	Pickle Cured (18) Percent Carbonyls		Dry Cured (19)
	Uncured	Cured	
Acetaldehyde	28.7	39.0	Formaldehyde
Propionaldehyde	22.0	53.9	Acetaldehyde
iso-Butyraldehyde			Propionaldehyde
Acetone			iso-Butyraldehyde
n-Butyraldehyde	0.7	0.5	n-Valeraldehyde
iso-Valeraldehyde	1.5	3.0	iso-Valeraldehyde
2-methyl butyraldehyde	0.9	1.8	Acetone
n-Valeraldehyde	4.4	0.5	Diacetyl
Hexanal	42.0	1.3	Methyl ethyl ketone
			Formic
			Acetic acid
			Propionic acid
			Butyric acid
			iso-Caproic acid

covered from the cured and uncured hams. The major differences appear to be in the larger quantities of n-valeraldehyde and hexanal that are present in the uncured ham.

The authors conclude that the nitrite interferes with oxidation of the unsaturated lipids. However, there also seems to be more acetaldehyde and propionaldehyde + acetone present in the cured meat that is not accounted for. The aroma of the volatiles after removal of the aldehydes was like cured ham whether the volatiles came from cured or uncured ham. However, after removal of the sulfur compounds that also were present, the characteristic odor disappeared.

Ockerman, Blumer and Craig (19) studied the volatiles of dry-cured, smoked hams. The list of compounds identified also is shown in Table 4. These authors did not

try to relate these chemicals to the flavor of the ham.

The headspace over a food will contain the volatile components present in the aroma. Headspace studies of canned beef aroma were made by Brennan and Bernhard (20). They treated meat in sealed jars for 90 minutes at 122° C. (15 psi. steam pressure) and then collected the vapors over the meat. Their tests indicated the presence of hydrogen sulfide, methanethiol, ethanethiol, propanethiol, butanethiol and methylformate.

The authors indicated that the differences between their findings and those in Table 3 may be due to the more rigorous conditions they used in the treatment of their meat. Also, they examined the vapor rather than the extract. This may be reflected in the fact that canned beef has a different flavor than boiled or roast beef. On separating the beef from the liquid, the juice was found to have the characteristic meaty flavor, suggesting that the water-soluble flavor components were extracted from the meat tissue.

ENHANCERS: An important aspect of meat flavor research is that group of components known as flavor enhancers. These are monosodium glutamate (MSG), disodium inosinate (IMP) and disodium guanylate (GMP). The flavor enhancers do not affect the aroma of the meat; pyrolysis of these compounds does not result in a meaty odor. However, they are reported to increase the meaty flavor of the material to which they are added in trace quantities. Their main action seems to reside in the "mouth-feel" imparted to the product.

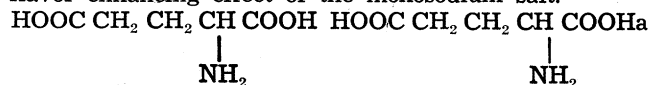
Monosodium glutamate, for instance, has an initial salty taste, followed by an increase in salivation and a feeling of "mouthfullness" toward the back of the mouth. There is a meaty character to this reaction. Many of the vegetable protein hydrolysates that are used as meat substitutes may rely on this effect inasmuch as they contain up to 20 per cent monosodium glutamate.

The nucleotides (IMP and GMP) are more effective as flavor enhancers than MSG, and GMP is five times as effective as IMP. Commercially, mixtures of the three enhancers are used to reduce the cost.

The method in which these compounds act is completely unknown. However, it is highly likely they do not react with the flavor components of the food product but in some way sensitize or affect the taste nerve endings in the mouth (the meaty, "mouth-feel" effect of MSG alone

indicates this). The enhancing effect depends on the structure of the compound.

Glutamic acid has two acid groups, and neutralizing both gives disodium glutamate which does not have the flavor enhancing effect of the monosodium salt.



Glutamic Acid Monosodium Glutamate (MSG)

The nucleotides, IMP and GMP, contain phosphorus in the 5'-position in their structure. If the phosphorus is in the 3'-position, they are not active. Other modifications in their structure also destroy the effectiveness of the two nucleotides. The 5'-nucleotides of other purines and pyrimidines that are either present or can be formed from meat components do not enhance flavor.

The study of meat flavors was limited in the past because the analytical techniques available did not allow us to isolate and identify the trace components that are involved. The newer, instrumental methods have shown that there are many more components in flavors than previously anticipated, and with the more sophisticated approaches now being used, the problems of meat flavors may be solved in the near future.

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